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**Continuation-In-Part**
**Patent Application of**
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**for**

# METHOD AND APPARATUS FOR IMPROVING SHEET FLOW WATER RIDES

SUB SPEC

## FIELD OF THE INVENTION:

The present invention relates in general to water rides, specifically a mechanism and process that provides a flowing body of water having flat, radial,and inclined surfaces thereon of sufficient area, depth and slope to permit surfboarding, skim-boarding, body-boarding, inner-tubing, and other water-skimming activity and, in particular, to several embodiments with means for generating, forming, maintaining, moving and riding said flow of water in a predominantly steady state condition.

## RELATED APPLICATIONS:

This application is a Continuation-In-Part of co-pending U.S. Application Serial No. 07/286,964, filed December 19, 1988 for IMPROVEMENTS IN SURFING-WAVE GENERATORS, to be issued as U.S. Patent No.4,954,014 on September 4, 1990, which is a Continuation-In-Part of U.S. Application Serial No. 07/054,521, filed May 27, 1987 for TUNNEL WAVE GENERATOR, issued as U.S. Patent No. 4,792,260 on December 20, 1988.

## BACKGROUND OF THE INVENTION:

For the past 25 years, surfboard riding and associated wave riding activities, e.g., knee-boarding, body or "Boogie" boarding, skim-boarding, surf-kayaking, inflatable riding, and body surfing (all hereinafter collectively referred to as wave-riding) have continued to grow in popularity along the world's surf endowed coastal shorelines. In concurrence, the 80's decade has witnessed phenomenal growth in the participatory family water recreation facility, i.e., the waterpark. Large pools with manufactured waves have been an integral component in such waterparks. Several classes of wavepools have successfully evolved. The most popular class is that which enables swimmers or inner-tube/inflatable mat riders to bob and float on the undulating swells generated by the wave apparatus. A few pools exist that provide large turbulent white-water bores that surge from deep to shallow pool end. Such pools enable wave-riding, however, white-water bore riding is not preferred by the cognosceti of the wave-riding world, rather the forward smooth water face of a curling or tubing wave that runs parallel to the shoreline holds the ultimate appeal. Although numerous attempts have been made to establish wave-riding on curling waves as a viable activity in the commercial waterpark wavepool setting, such attempts have met with limited success. The reasons which underlie wave-riding's limited waterpark success is four-fold, 1) small spilling or unbroken waves which are ideal for the mass of novice waterpark attendees are not ideal for intermediate or advanced wave-riders; 2) the larger waves ideal for wave-riding have proven prohibitive in cost to duplicate and become inherently more dangerous as their size increases; 3) the curling and plunging waves sought by advanced wave riders require steep and irregular pool bottom configurations that are inherently dangerous and can cause strong deep water currents; 4) assuming a compromised and safer wave shape is acceptable to wave-riding participants, wave-riding is ideally a one-man-to-one-wave event that monopolizes an extended surface area. As a consequence of limited wave quality, excessive cost, potential liability, and large surface area to low rider capacity ratios, wavepools specifically designed for wave-riders have proven unjustifiable to water park operators.

All wavepools that currently exist in the waterpark industry and the majority of previously disclosed wave-making inventions attempt to duplicate those types of oscillatory waves found naturally occurring at a beach. For purposes of definition, such waves are hereinafter termed "natural waves". Natural waves also include those found occurring in rivers as caused by submerged obstacles e.g., boulders. As known to those skilled in the art, natural waves have specific characteristics capable of mathematical description as a funtion of wave length, wave height, period, wave angle, velocity, phase speed, break speed, gravity, free surface water elevation, water depth, etc. Additionally, mathematically descriptions can be provided for a wide range of wave shapes progressing from an unbroken-to breaking-to broken. Breaking waves, those of

most interest to wave-riders, are traditionally classified as either spilling, plunging or surging. Broken waves can either be stationary (e.g., a river impacting on an obstacle creating a stationary hydraulic jump), or moving (e.g., an ocean white water surge or bore characterized by rapidly varied unsteady flow). The shape of a breaking wave is primarily a function of a given set of the aforementioned wave characteristics and the contour of the bottom over which the wave is moving. Beginning wave-riders prefer the smaller gentle spilling wave produced by a gradually sloped bottom surface. Advanced wave-riders prefer the larger plunging breakers that result from a steeply inclined beach. Since there are demographically a greater number of beginning wave-riders and since the wave favored by beginning riders is a product of an inherently safer gentle incline of beach, and since the energy and cost required to produce a small spilling wave is exponentially less than required to produce a large plunging wave, the current genre of wave pools have by necessity and practicality not been suitable for wave-riding by the more advanced wave rider.

The subject invention aims at creating a "wave shape" that can serve to provide those types of "wave shapes" desired by intermediate to advanced riders. Additionally, the subject invention seeks to accomplish such "wave shape" creation at a fraction of the cost and with an improved margin of safety as compared to that required to duplicate the aforementioned intermediate to advanced natural waves. The reason the subject invention can succeed at its goal is that it does not duplicate natural waves, rather, it creates "flow shapes" that are a result of high velocity sheet flows over a suitably shaped forming surface. This concept of sheet flow formation versus natural wave formation is one of two primary distinguishing factors between the subject invention and the prior art.

This second distinguising factor focuses on the forces that "drive" a wave-rider when he is riding a wave. To this end, the subject invention defines two distinct classes of flow shapes, i.e., deep water flow shapes and shallow water flow shapes. A deep water flow shape is where the water depth is sufficient such that boundary layer effects of the sheet flow over the forming surface <u>does not influence</u> the operation of rider or riding vehicle, e.g., surfboard. Deep water flow shapes can, assuming certain flow forming and flow characteristics (e.g., velocity) are met, duplicate naturally occurring waves. A shallow water flow shape is where the water is of such depth that the surface boundary layer effects of the sheet flow over the forming surface <u>influences</u> the operation of rider or riding vehicle, e.g., surfboard. As contemplated by the subject invention, shallow water flow shapes will never duplicate naturally occurring waves, because there are differing forces that come into play when a rider rides the respective wave or flow. As the result

of these differing forces, the operational dynamics of the subject invention require that for shallow flows the average velocity of the water sheeting over the flow forming surface will always exceed the maximum velocity which would be found in a natural wave. To better explain why the shallow water flow velocity must always be greater than that of a deep water flow, and to further expand on the forces involved when a surfer rides an ocean wave or conversely when a "skimmer" rides a shallow water flow, the following examples are given: On a natural wave (a deep water flow environment) a surfer prior to starting a ride begins to move up the slope of the coming wave by primarily the forces of buoyancy. In order to overcome the forces of fluid drag, the surfer commences to paddle and take advantage of the interaction between the forces of buoyancy and gravity to provide a forward component to the surfboard and achieve riding speed. Thereafter, maintenance of a steady state position riding normal to the wave front is a balancing act between on the one hand, the while maintaining the same position on the stationary wave requires hydrodynamic lift forces on the bottom of the surfboard and buoyancy, and on the other hand, to provide the forces to overcome the forces of gravity and fluid drag. Cutting Trimming across the wave front (at an angle to the wave front) requires the same balancing act. If one attempts to reproduce the above describe scenario in natural flow conditions, a large water depth is required. Likewise, in the laboratory (amusement park) setting this can be accomplished by deep water flows (reference the Killen papers, infra).

Conversely, in a shallow water flow environment, the forward force component of the "skimmer" and skimming device required to maintain a riding position and overcome fluid drag is due to the downslope component of the gravity force created by the constraint of the solid flow forming surface balanced primarily by momentum transfer from the high velocity upward shooting flow. The "skimmer's" motion upslope (in excess of the kinetic energy of the "skimmer") consists of the force of the upward shooting flow exceeding the downslope component of gravity. In both deep water and shallow water flow environments, Non-equilibrium riding maneuvers such as cross-slope motion and oscillating between different elevations are made possible by the interaction between the respective forces as described above and the use of the rider's kinetic energy.

The parent inventions to the subject application have focused upon deepwater flow shapes specific to the performance of "surfing maneuvers". Surfing maneuvers, is defined by those skilled in the art, as those which occur under ocean like hydrodynamic conditions. Consequently, surfing maneuvers can be performed in an artificial environment, e.g., a wavepool, assuming that the wave which is produced duplicates the ocean wave riding experience (deep water flow) as described above. By corollary, true surfing maneuvers cannot

be performed in shallow flow environments since the hydrodynamic conditions are distinct. However, full scale tests have demonstrated that the physical look and feel of "surfing like maneuvers" performed in a shallow flow are surprisingly similar to "real" surfing maneuvers performed in a deep flow. For purposes of technical clarity, shallow flow "surfing type maneuvers" shall be termed as a subset of what hereafter can be described as "water skimming maneuvers". Water skimming maneuvers are defined as those activities which can be performed on shallow water flows including "surfing like maneuvers" as well as other activities or other types of manuevers with differing types of vehicles e.g. inner-tubes, bodyboards, etc.

The subject invention discloses improvements to the prior art of shallow water flows, as well as, similar improvements to the deep water flow shapes of the parent invention. The parent invention generated two types of stationary flow shapes, i.e., a stationary peeling tunnel flow shape for advanced waveriders, and a stationary non-breaking upwardly inclined flow shape for beginners. One aim of the subject invention is to apply the principals of shallow flows to the flow forming surfaces of the parent invention. Such improvements are hereinafter referred to as the "Shallow Flow Tunnel Wave Generator" and the "Shallow Flow Inclined Surface."

A second aim of the subject invention results from connecting specified flow forming surfaces in quantifiable proportions to facilitate increases in rider speed and available rider maneuvers that would be impossible, but for, such proportionately connected surfaces. This deep and shallow water improvement is hereinafter referred to as the "Connected Structure" and the method of increasing ones acceleration is hereinafter termed the "Acceleration Process".

A third aim of the subject invention is to improve the free flow start capabilities of an inclined flow forming surface by lowering the downstream boundary area of this surface at an angle so as to create a maximum height ridge line of decreasing elevation to facilitate self-clearing of undesirable transitory surges, this deep and shallow water improvement is hereinafter referred to as the "Self-Clearing Incline".

A novel ramification to the "Self-Clearing Incline" occurs by extending the inclined flow forming surface and associated ridge line of the downstream boundary area to an increased elevation. If such increase in elevation is in excess of the net total head flow necessary to flow over this new increase in elevation, then the flow will form a hydraulic jump and the sub-critical water thereof will spill down the upwardly sheeting flow in the manner of a spilling wave. The fourth aim of the subject invention is to intentionally duplicate this phenomena in both deep and shallow flow environments. Such

improvement is hereinafter called the "Inclined Riding Surface with Spilling Wave").

A fifth deep and shallow water flow improvement of the subject invention is the combination of tunnel and inclined flow forming surfaces, as well as, creation of an intermediate "spilling wave" that works in combination with the inclined surface. Such embodiment is hereinafter referred to as the "Omni-Wave". A further feature of the Omni-Wave embodiment is its unique flow forming shape can permit (by way of changes to the head of the sheet flow) the transformation of the sheet flow from a stationary "spilling wave" to a combination "spilling wave" and inclined planar wave shape, and ultimately to a combination inclined surface and tunnel wave shape. This unique feature is hereinafter referred to as the "Wave Transformation Process".

A sixth deep and shallow water flow improvement of the subject invention is through selective combination of the above described improvements to form a flow forming configuration that resembles a longitudinally oriented half-pipe. This embodiment is hereinafter referred to as the "Fluid Half-Pipe." The Fluid Half Pipe offers unique ride characteristics analogous to such configurations in the sports of skateboarding and snowboarding.

The final aim of the present invention is the positioning of dividers within a Half-Pipe or Inclined Surface as described above to provide separation for the individual riders and to prevent a "jet wash" phenomenon that can result in loss of a rider's flow. Such improvement is hereinafter referred to as "Sheet Flow Dividers."

## DISCUSSION OF PRIOR ART:

The water recreation field is replete with inventions that generate waves yet lacking as to inventions that create flow formed wave-like shapes. In all cases, none to date describe the improvements contemplated by the subject invention, as an examination of some representative references will reveal.

To facilitate distinction, the prior art can divided into seven broad wave or wave shape forming categories:

Category 1 - an oscillating back-and-forth or periodic up-and-down movement by an object or pressure source that results in disturbance propagation from point to point over a free water surface. Representative prior art: Fisch U.S. Pat. No. 1,655,498, issued Jan. 10, 1928, describes an

artificial surf-bathing pool in which a tank was shown adapted to rock with a shifting fulcrum in order to create a wave which breaks over bathers in the tank. Fisch U.S. Pat. No. 1,701,842, issued Feb. 12, 1929, describes an artificial surf-bathing pool comprising a tank adapted to cyclically oscillate on a knife edge in order to induce a surge of water towards the ends of the tank. Keller U.S. Pat. No. 1,871,215 issued Aug. 9, 1932, discloses a machine that causes a log to roll into a pool of water, the displacement of which produces the desired wave motion and surf for bathers in the pool. Matrai U.S. Pat. 3,005,207, issued October 24, 1961, discloses a swimming pool with an oscillating paddle in a deep chamber which provides simulated ocean waves for the enjoyment of bathers in both deep and shallow portions of the pool, respectively. Anderson U.S. Pat. No. 3,477,233, issued Nov. 11, 1969, discloses a machine that periodically moves an elongated rotating buoyant member resulting in gravity waves on the surface of a liquid, for use in mixing liquids, causing mass transport of floating surface matter, and breaking up ice formations. Presnell et al U.S. Pat. No. 3,478,444, issued Nov. 18, 1969 describes a simulator device for studying and demonstrating wave, current, and wind action on and in a body of water, including a plenum chamber which is connected to a pneumatic compressor and valving system to generate sinusoidal wave action on the liquid. Koster U.S. Pat. No. 3,562,823, issued Feb. 16, 1971, discloses a wave-making machine for swimming pools, which depends upon the back and forth movement of a sub-merged vane in a pool of water to create a wave, and utilizes a resonance effect to minimize energy usage and obtain desired large waves. Anderson U.S. Pat. No. 4,201,496, issued May 6, 1980, discloses a further improvement on the wavemaking machine of Andersen '233, above, which depends upon the periodic up-and down-movement of a massive body in water to create the desired waves. Baker U.S. Pat. No. 4,276,664 issued July 7, 1981, discloses an apparatus for wave-making which also, like Andersen '496, depends upon periodic up-and-down movements of a massive body in water to create desirable waves, perhaps exploiting a resonance effect.

The structure and operation of Category 1 prior art illustrate those types of devices which generate waves in an unsteady flow, i.e., a wave profile which will vary over distance and time. The subject invention provides a steady state wave shape which need not vary over time and does not have a distance of travel component. Furthermore, the structure of the subject invention does not teach disturbance propagation of a wave from point to point over the free water surface. Consequently, Category 1 prior art has no relevance to the subject invention.

Category 2 - a moving hydraulic jump caused by the release of a quantity of water. Representative prior art: Dexter U.S. Pat. No. 3,473,334, issued Oct. 21,

1969 discloses a wavemaking apparatus which depends upon the release of a large volume of water into a pool, with a white water bore created by the shape of the water outlet or the contour of the pool bottom. Bastenhof U.S. Pat. No. 4,522,535, issued June 11, 1985, discloses a surf wave generator which depends upon the release of a large volume of water into a pool, with shape of the wave being created by the contour of the pool bottom. Schuster, et al U.S. Pat. No. 4,536,719, issued Sept. 10, 1985, discloses a method and pneumatic apparatus which like Bastenhof, also depends upon the release of a large volume of water into a pool for surf wave production, with the wave shape being created by the contour of the pool bottom.

Although differing in method, the structure and operation of Category 2 prior art is similar to Category 1 in that they generate waves in an unsteady flow, i.e., a wave profile which will vary over distance and time. The subject invention provides a steady state wave shape which need not vary over time and does not have a distance of travel component. Furthermore, the wave height as generated by Category 2 devices will diminish as these waves dissipate energy in their line of travel. Conversely, in the subject invention water can be constantly added to the wave form to keep its height constant. As to the issues of water depth, direction of flow and direction of wave spill, the channel or pool bottoms of Category 2 devices constantly change in depth and become more shallow as one moves in the direction of the traveling wave and released water. Conversely, in the subject invention as one moves in the direction of water flow up the incline the water becomes deeper and a spilling wave (if present) will spill in a direction that is opposite to the direction of released water flow. For the above stated reasons, it should be evident that Category 2 prior art has no relevance to the subject invention.

Category 3 - a stationary hydraulic jump resulting in a spilling wave. Representative prior art: Le Mehaute U.S. Pat. No. 3,802,697 discloses a water filled channel with a wedge shaped wave forming body positioned in the channel so that water which flows over the wedge with requisite depth and velocity is deflected by the upper surface of the wedge to generate a hydraulic jump suitable for surf-riding. Le Mehaute shares an attribute of the "Inclined Riding Surface with Spilling Wave" embodiments of the subject invention, i.e., the ability to generate a stationary hydraulic jump resulting in a spilling wave. However, Le Mehaute can be clearly distinguished from the subject invention as follows: The entire thrust of Le Mehaute is the creation of a hydraulic jump in an open channel by abrupt modification of the depth of the channel, e.g., placing an obstruction in the channel. This obstruction, or wave forming means, causes the water which flows thereover to "deflect" and induce a hydraulic jump and associated spilling wave. The physical orientation

of the deflecting surface is always oblique to the prevailing direction of water in the channel.

Conversely, in both deep water flow and shallow water flow embodiments for the subject invention the inclined surface over which water flows by definition does not "deflect" the water which flows thereover and is not necessarily oblique to the prevailing direction of surface water flow. Rather, at any given point a super-critical stream of water flows (with a depth profile at that point) predominantly tangential to the surface of the incline. A user who is riding this flow of water is not depending upon an induced hydraulic jump wave to provide an appropriate angled flow upon which to ride, rather the inclined surface itself maintains the requiste angle of flow, irrespective of the presence of any hydraulic jump. In the event a hydraulic jump should form upon the inclined surface of the subject invention e.g., as described in the "Inclined Riding Surface with Spilling Wave", it should be recognized that such formation is not essential to the flow riding experience and is strictly a local phenomena caused by the flow having insufficient kinetic energy to continue up the incline. The spilling wave associated with this hydraulic jump can vary in position along the incline (e.g., remain frothing at the point of the jump or tumble down to some equilibrium point near the bottom of the incline) dependent upon how efficiently sub-critical water is vented or removed. When expressed in its simplest terms, Le Mehaute creates his hydraulic jump and associated spilling wave by bouncing water off of an inclined surface. The subject invention creates its hydraulic jump and associated spilling wave by conforming water to a non-deflective inclined surface with a portion thereof having height in excess of the net total head (net of friction losses) of the upwardly flowing stream. The deflective angle of incidence which Le Mehaute seeks to produce is exactly the effect that the subject invention seeks to avoid. It is respectfully submitted that on this matter Le Mehaute teaches away from the structure of the subject invention.

Specific to the shallow flow embodiments of the subject invention, another distinguishing feature centers upon the issue of vehicle/rider buoyancy. The surfboards or boats in Le Mehaute are described as "buoyant carriers" which are then moved by the hydraulic jump created by the wave forming means, thereby simulating surfriding to a rider positioned on the buoyant carrier. Column 2, Line 19 through 23. By definition, the depth of the water in Le Mehaute must be sufficient to support the "buoyant carrier" by the forces of displaced water, i.e., buoyancy forces. Conversely, in the shallow water flow embodiments of the subject invention the support for the surfboard/riding vehicle is primarily provided by dynamic hydroplaning pressures created by the interaction between the surfboard, the upward sheeting flow, and the solid

surface of the ride forming means. Buoyancy forces serve as a secondary support factor.

In that Le Mehaute attempts to duplicate a "natural" standing wave, there are specific relationships between the angle of flow relative to the obstacle, the velocity of flow and the overall wave velocity field. These relationships must be maintained or the "wave" as defined by Le Mehaute will not form. Conversely, in the subject invention one need or cannot conform to these "natural wave" specifications. For example, in deep water flows since one can control the velocity of the sheeting water one can choose to exceed the parameters as found in nature. In shallow water flows, by functional necessity, the velocity of the flow must always exceed that which is found in nature at comparable water depth due to the lack of buoyancy forces and the need to substitute the hydrodynamic "ground" and hydroplaning effects.

Category 4 - a moving hydraulic jump caused by a moving hull. Representative prior art: Le Mehaute '697 (supra) also disclosed movement by a wedge shaped body through a non-moving or counter-moving body of water, with such movement causing a hydraulic jump and resultant spilling wave suitable for surf-riding. The moving hydraulic jump of Le Mehaute can be distinguished from the subject invention based upon the previous '697 discussion and upon the obvious structural distinction that Le Mehaute teaches movment of the wave forming means while the subject invention remains stationary.

Forsman U.S. Pat. No. 3,913,332, issued Oct. 21, 1975, discloses a continuous wave surfing facility, which uses a wave-forming generator consisting of a single or double plow-shaped blade moving through an annularly-shaped body of water to form surfing waves of desired shape and size. Both single and double wave-forming blades are disclosed, propelled by a vehicle which moves along annular rails, submerged or otherwise, and generates a continuous wave for each blade which is suitable for surfing. Multiple generators can be employed to produce serial waves so that several surfers can enjoy the facility simultaneously. Provision is made for changing wave characteristics by changing the horizontal angle of the blades relative to the direction of motion, the leading edge of the blade, whether double or single, being hinged. Besides the obvious structural distinction that Forsman's wave forming means moves, while the subject invention remains stationary, there are two other grounds upon which Forsman can be distinguished. First, the translatory white water wave that is formed by Forsman is the product of a massive hydraulic jump that occurs when the moving plow deflects the water through which it passes. As previously discussed in Le Mehaute '697, a hydraulic jump/spilling wave that results from deflection is structurally different from a hydraulic jump/spilling wave that results from non-deflective friction and gravity

forces acting upon a flow forming surface that is predominantly tangential to the surface flow (the teaching of the subject invention). Second, the structure and operation of Forsman's apparatus exhibits unsteady state wave generation. The subject invention can exhibit steady state wave form generation.

Category 5 - a wave shape that similates a stationary unbroken wave. Representative prior art: Frenzl U.S. Pat. No. 3,598,402 issued Aug. 10, 1971 is perhaps more closely related in structure to the shallow water flow embodiments of the present invention than any of the previously discussed references. Frenzl discloses an appliance for practicing aquatic sports such as surf-riding, water-skiing and swimming comprised of a vat, the bottom of which is upwardly sloping and has a longitudinal section which shows a concavity facing upwards while a stream of water is caused to flow upslope over said bottom as produced by a nozzle discharging water unto the surface of the lower end of said bottom. Provision is made for adjustment of the slope of the vat bottom around a pivotal horizontal axis to permit the appliance to be adjusted for that sport which has been selected for practice, e.g., water skiing reduced slope or surf-riding increased slope. Provision is also made for varying the speed of the water from a "torrential flow" for water skimming activities, e.g. surfboard riding, to a "river type flow" wherein the speed of the water is matched to the speed of an exercising swimmer. However, Frenzl '402 does not recognize, either explicitly or implicitly some of the problems solved and advantages proffered by the present invention. A comparative analysis of Frenzl's teaching with the structure of the embodiments as described herein will serve to illustrate substantive differences. In the instance of "torrential flow", Frenzl teaches that the function of his structure,

"allow(s) the practicing of surf-riding and other similar sports, as the sloping of the vat bottom results in the possibility for the water skier to keep his balance <u>in an equilibrium position</u> depending on the one hand, on an upwardly directed force ascribable to the drag or resistance of the carrier board or boards dipped into the stream of water and, on the other hand, on a downwardly directed force produced by the component of the weight of the water skier in a direction parallel with the vat bottom." (Frenzl, Col. 1 lines 49 - 57, underlining added).

In the instance of a "river type flow", Frenzl teaches that the function of his structure,

"allows also practicing swimming. To this end, the swimmer sets the bottom 1 into a slightly sloping position... and he fills the vat almost up to its upper edge. He resorts then to low speeds for the water stream... <u>The stream of</u>

water may be adjusted, so as to match the speed of the swimmer..." (Frenzl, Col. 4 lines 14 -22, underlining added).

In both flow descriptions, the entire teaching of Frenzl is for the user of the apparatus to be in equilibrium so that aquatic sport equilibrium training can be practiced by the user. Either a user is in static equilibrium while skimming the surface of the water or in static equilibrium when swimming through the water. All adjustments to Frenzl's appliance are directed at creating or sustaining this equilibrium. Conversely, the teaching of the subject invention is to avoid equilibrium. This desire for disequilibrium manifests itself structurally in two separate areas, a "supra-equidyne area" that extends downstream of Frenzl's "equilibrium zone", and a "sub-equidyne area" that extends upstream of Frenzl's "equilibrium zone". The term "equilibrium zone" as used herein is meant to define Frenzl's claimed structure. The "supra-equidyne area" (a structural feature present in the parent invention as well as all embodiments of the subject invention) is defined as that portion of the riding surface wherein the slope of the incline is sufficiently steep to enable a rider to overcome the upwardly sheeting water flow and slide downwardly thereupon. Since Frenzl taught only equilibrium, Frenzl had no need for a structure (i.e., a supra-equidyne area) which by design results in a disequilibrium producing downward slide. In the subject invention, the purpose of such structure is to allow the performance of surfing type maneuvers upon the water that moves up the inclined surface. As is well known to those skilled in the art of surfing, such maneuvers include riding across the face of the surface of water, moving down the surface toward the lower end thereof, manipulating the riding vehicle to cut into the surface of water so as to carve an upwardly arcing turn, riding back up along the face of the inclined surface of the body of water and cutting-back so as to return down and across the face of the body of water and the like. All of such maneuvering activity encompassed with the term "surfing maneuvers" in deep water flow environments and "water skimming maneuvers" in shallow water flow environments is not desired by Frenzl. In fact, Frenzl teaches that his structure (i.e., the equilibrium zone) is specifically designed to minimize the very maneuvers that the subject invention seeks to encourage. Frenzl states:

"A theoretical and experimental investigation of the appliance has shown as a matter of fact that the position of equilibrium of the user as referred to hereinabove may, under certain conditions, lack stability. It may occur, during operation, that the user changes suddenly the position of the board or boards carrying him with reference to the water surface, for instance when he simulates sudden movements such as turns, side slips, snow ploughs or the like. This may lead to a substantial alteration of the upwardly directed force referred to thereinabove and thereby either to a sudden sinking of the water

skier whose weight has thus become suddenly predominant down to the lower end of the bottom or else in the opposite case, to a rising of the water skier into immediate proximity with the upper end of said bottom. It has been found that the concavity in the longitudinal section of the bottom of the vat cooperates in a positive manner in ensuring stability by introducing into the equation defining the position of equilibrium referred to hereinabove a stabilizing factor..." (Frenzl, Col. 1 lines 68 -75 and Col. 2 lines 1-11).

It is respectfully submitted that Frenzl, in fact teaches away from the structure (supra-equidyne area) of the subject invention in that Frenzl is clearly limited to a training appliance that supports its participants in equilibrium. Furthermore, Frenzl does not seek the "surfing maneuvers" or "water-skimming maneuvers" as taught by the subject invention and such maneuvers are rendered difficult, if not impossible, to perform without the proper structure (supra-equidyne area) to facilitate performance thereof.

Frenzl limits the practice of his aquatic sport to an upward incline (Reference Col. 1 Lines 44-47). He further defines his equilibrium zone as a function of the aquatic sport to be performed but in any event limited to a specific range of inclination (Frenzl Col. 3 Lines 42-45)

Frenzl teaches that the sport of "surf-riding" is further limited to "steeper slopes" (Frenzl Col.3 Lines 59-61). Frenzl does not contemplate the possibility that water flow over a horizontal surface without slope (as defined by the sub-equidyne area) can be used to perform surfing maneuvers as contemplated by the "Connected Structure" embodiment as further described herein. Furthermore, theoretical and experimental investigation of a prototype embodiment of the "Connected Structure" has shown that proper integration of supra-equidyne area, equilibrium zone and sub-equidyne area results in synergism, i.e., the Connected Structure as a whole enables the performance of surfing maneuvers far superior to that which can be accomplished by its respective parts. It is respectfully submitted that Frenzl teaches away from the sub-equidyne structure as taught by the subject invention.

Frenzl U.S. Pat. No. 4,564,190 issued Jan. 14, 1986 shows improvements to the appliance for practicing aquatic sports using gliding devices (as disclosed in the Frenzl '402 patent) by introduction of a device that removes water from an upwardly sloping bottom surface which has been slowed down by friction at the boundary faces and returns the water to a pumping system to thereby increase the flow rate and thus eliminate the deleterious effects of slowed

down water. The improvements as described by Frenzl '190 have no relevance to the subject invention.

Frenzi U.S. Pat. No. 4,905,987 issued Mar. 6, 1990 shows improvements to the appliance disclosed in the Frenzl '402 patent (described above) by showing connected areas for swimming, non-swimming and a whirlpool so that water from the Frenzl '402 appliance is further utilized after outflow thereof. The primary objective of the Frenzi '987 patent is to improve the start and exit characteristics of the Frenzl '402 appliance by providing a means whereby a user can enter, ride, and exit the appliance to avoid breakdown of the torrential flow. The improvements as described by Frenzi '987 have no relevance to the subject invention.

Category 6 - a deflective wave shape that simulates a stationary tunnel wave. Representative prior art: **Hornung, H.G. and Killen, P., "A Stationary Oblique Breaking Wave for Laboratory Testing of Surfboards", Journal of Fluid** Mechanics (1976), Vol. 78, Part 3, pages 459-484. **P.D. Killen, "Model Studies of a Wave Riding Facility", 7th Australasian Hydraulics and Fluid Mechanics Conference, Brisbance, (1980).** P.D. Killen and R. J. Stalker, "A facility for Wave Riding Research", Eighth Australasian Fluid Mechanics Conference, University of Newcastle, N.S.W. (1983). The apparatus taught by Killen (all three articles will be collectively referred to as Killen, and each article is specifically referenced by chronological date of publication) forms a wave shape of the type favored by surfboard riders, by placing a suitably shaped fixed position obstacle in a channel of specified width and in the path of a flow of water with specified depth and velocity such that deflection of the water off the obstacle duplicates the geometric and hydrodynamic aspects of a surface gravity wave that is obliquely incident to a sloping beach. At first glance, it may appear that structure as taught by Killen and that as disclosed by the subject invention are substantially similar. However, close examination will reveal significant differences, the first of which centers upon the orientation of the flow forming surface to the direction of water flow and the consequences that result therefrom. At page 464 of the 1976 article, it is stated, "The final form of the obstacle is shown in figure 3 in the form of a contour map. It can be seen that only a slight curvature has been built into the contours on the obstacle face and that the tip builds up gradually in a backward sweep, leaving a space for the channel-wall boundary layer to be washed past outside the region of interest." By visual analysis of Killen's Figure 3 and Figure 5 (wherein Figure 5 shows the obstacle of Figure 3 in operation), it is indicated that the angle of incidence of water impacting the obstacle ranges (depending upon the depth of the flow) from tangential to near perpendicular along the y axis and from near perpendicular to approximately 45

degrees along the x axis; consequently the water striking the obstacle forms a curling flow by deflecting in a range from upward to backward to simulate the ideal surfing type wave. At page 462, Killen by analogy to a gas flow states, "a stationary oblique wave may be generated by deflecting the flow with a wedge." Clearly, Killen teaches that the structure of his obstacle is intended to deflect. The flow lines of Killen separate from the surface over which it flows. Conversely, the subject invention does not deflect water off of an obstacle to form the tunnel wave as taught by Killen, rather the angle of incidence of the entire depth range of sheeting water at a particular point relative to the inclined surface over which it flows at that point is predominantly tangential. Consequently, the water which flows upon the inclined surface conforms to gradual changes in inclination (i.e., a non-separated flow). "Conformity" as taught by the subject invention requires that the "tunnel" portion of the subject invention's tunnel flow result from non-separation of the flow's surface <u>and sub-surface</u> stream lines with causal agent for the "tunnel" attributal to the beyond vertical release angle of the further-most downstream edge of the flow forming surface. As demonstrated by Killen, deflection does not require an angle of release that is beyond the vertical in order to form a tunnel wave. To further illustrate this point of distinction, if one were to place a "conforming flow" of the subject invention in operation upon Killen's structure, a tunnel wave could not form because the final angle of release on Killen's structure does not exceed the vertical. When expressed in terms of water depth and obstacle structure vis-a-vis the trajectory of water release at the downstream termination of the obstacle, the composite range in depth of Killen's water flow and its resultant obstacle deflection enables the water flow to bend back and form a tunnel wave without requiring the downstream termination of the obstacle to physically direct and point the flow in an arching upstream trajectory. Conversely, the subject invention creates its tunnel wave by conforming water to a surface of such gradual curvature (relative to the flows thickness) that deflection does not occur and the downstream termination of the surface <u>must</u> physically direct and point the flow in the proper upstream trajectory. The deflective angle of incidence which Killen seeks to produce is exactly the effect that the subject invention seeks to avoid. It is respectfully submitted that on this matter Killen teaches away from the structure of the subject invention.

Killen goes on to define his optimum wave performance characteristics as a function of water depth, water velocity, channel width and obstacle position. Specific to water depth, Killen states in the1980 article (page 51) that the water depth of the channel must be "such that the boundary layer on the test section floor does not interfere with the flow around the surfboard fin for suitable range of wave shapes. A maximum channel depth of one half of the maximum wave-face height has been found to be adequate." In the 1983

article (page 2B.1), Killen states, "The channel depth must be such that the clearance between the surface of the wave making obstacle and the surfboard hull, when the board is riding on the wave, is sufficient to avoid effects similar to the "ground effect" experienced with very low flying aircraft or the proximity of a wall in wind tunnel testing (e.g., enhanced lift and drag coefficients and increased lift/drag ratio caused by the change in flow direction near the stationary boundary)." Conversely, in shallow flow embodiments of the subject invention there is no requirement for a channel to retain the water flow at a requisite depth. In fact, a preferred embodiment of the subject invention is to project a water flow across an inclined surface without water retaining (channel) walls of any type. Consequently, Killen's defined relationship between the depth of the channel and the wave-face height is irrelevant when referenced to the structure of the subject invention. In addition to the forgoing, interference due to boundary layer effects from the floor/wave-making obstacle or the surfboard hull/fin is not an adverse concern in the shallow flow embodiments of the subject invention. In fact, the "ground effects" which Killen seeks to avoid are exactly the effects that the subject shallow flow embodiments prefer. It is respectfully submitted that Killen on the point of "ground effects" teaches away from the structure of the shallow flow embodiments of the subject invention. Specific to obstacle position and channel width, Killen states in the 1976 article (page 464) "it is essential to terminate the obstacle about half way across the flume to prevent choking of the flow by the wave." Conversely, in the shallow flow embodiments of the subject invention if one were to place a properly configured inclined surface within a walled channel, the requisite gap between the inclined surface and channel wall could be substantially less than the midpoint due to significant reductions in water flow that need flow through the gap. In the 1980 (page 51) and 1983 (page 2B.1) articles, Killen states "Channel width should be about five times the height of the wave-face so that the behavior of the model surfboards can be studied over a suitable range of wave surface, curvature and steepness." Conversely, in the subject invention, the desired width of flow is subjective. At a minimum, it need only be as wide as is required to perform the desired water skimming activity thereon; for example, if the skimming activity is body surfing, then the width need only be as wide as the human being performing the surfing activity.

In that Killen attempts to duplicate a "natural" standing tunnel wave, there are specific relationships between the angle of flow relative to the obstacle, the velocity of flow, the depth of flow, and the overall wave velocity field. These relationships must be maintained or the "tunnel wave" as defined by Killen will not properly form, i.e, it would not be a wave that is naturally found in the ocean upon which a surfboard could ride. Conversely, in the subject invention one need or cannot conform to these "natural wave"

specifications. For example, in deep water flows since one can control the velocity of the sheeting water one can choose to exceed the parameters as found in nature. In shallow water flows, by functional necessity, the velocity of the flow must always exceed that which is found in nature at comparable water depth due to the lack of buoyancy forces and the need to substitute momentum transfer and hydrodynamic "ground" and hydroplaning effects.

In summary, Killen was attempting to create a wave shape that was geometrically and hydrodynamically similar to the ideal wave in the real surfing situation. The "conforming wave shape" as formed by the shallow water flows of the subject invention does not attempt to geometrically and hydrodynamically simulate the ideal wave in the real surfing situation. The "conforming" deep water flows of the subject invention do not require such simulation, even though they can so simulate.

## SUMMARY OF INVENTION

To better understand the objects and advantages of the invention as described herein, a list of special terms as used herein are defined:

(1) "deep water flow": that flow whereby the water depth is sufficient such that boundary layer effects of the sheet flow over the forming surface <u>does not influence</u> the operation of rider or riding vehicle, e.g., surfboard. Deep water flow shapes can, assuming certain flow forming and flow characteristics (e.g., velocity) are met, duplicate naturally occurring waves.

(2) "shallow water flow": that flow whereby the water is of such depth that the surface boundary layer effects of the sheet flow over the forming surface <u>influences</u> the operation of rider or riding vehicle, e.g., surfboard. Shallow water flow shapes will never duplicate naturally occuring waves.

(3) "surfing maneuvers": those maneuvers capable of performance on a surfboard which occur under ocean like hydrodynamic conditions, including deep water flows with the appropriate ocean approximating flow characteristics. Surfing maneuvers include riding across the face of the surface of water on a surfboard, moving down the surface toward the lower end thereof, manipulating the surfboard to cut into the surface of water so as to carve an upwardly arcing turn, riding back up along the face of the inclined surface of the body of water and cutting-back so as to return down and across the face of the body of water and the like. e.g., lip bashing, floaters, inverts, aerials, 360's, etc.

(4) "water skimming maneuvers": those maneuvers which can be performed on shallow water flows including "surfing like maneuvers" (i.e., similar to those described in "surfing maneuvers above) as well as, other activities or other types of manuevers with differing types of vehicles e.g. inner-tubes, bodyboards, etc.

(5) "body of water": a volume of water wherein the flow of water comprising that body is constantly changing, and with a shape thereof at least of a length, breadth and depth sufficient to permit surfing or water skimming maneuvers thereon as limited or expanded by the respective type of flow, i.e., deep water or shallow water;

(6) "conform (conformed, conforming)", where the angle of incidence of the entire depth range of a body of water is (at a particular point relative to the inclined flow forming surface over which it flows) predominantly tangential to said surface. Consequently, water which flows upon an inclined surface can conform to gradual changes in inclination, e.g., curves, without causing the flow to deflect. As a consequence of flow conformity, the downstream termination of an inclined surface will always physically direct and point the flow in a direction aligned with the downstream termination surface. A conformed water flow is a non-separated water flow and a deflected water flow is a separated water flow, as the terms separated and non-separated are known by those skilled in the art.

(7) "equilibrium zone": that portion of an upwardly inclined body of water wherein a rider is in equilibrium depending on the one hand, on an upwardly directed force ascribable to the drag or resistance of the riders vehicle or body dipped into the stream of water and, on the other hand, on a downwardly directed force produced by the component of the weight of the rider in a direction parallel with the inclined water forming means.

(8) "supra-equidyne area": that portion of a body of water above the equilibrium zone wherein the slope of the incline is sufficiently steep to enable a rider to overcome the upwardly sheeting water flow and slide downwardly thereupon.

(9) "sub-equidyne area": that portion of a body of water below the equilibrium zone that is predominantly horizontal. In the sub-equidyne area a rider cannot achieve equilibrium and will eventually (due to the forces of fluid drag) be moved back up the incline.

embodiment, as well as improving the performance parameters of prior art shallow water flow embodiments, e.g., as described by Frenzl. In Frenzl's embodiment, water was sheeted up a vat with an inclined bottom surface. The bottom surface was intentionally configured as an equilibrium zone. The rider was limited to equilibrium maneuvers, e.g., downslope facing with adjustments to one center of gravity resulting in modest motion within the confines of the vat. True surfing maneuvers were not possible given that the water flow did not approximate ocean flow characteristics. Furthermore, water skimming maneuvers were severely limited, although, a rider could practice his ability to balance in equilibrium. The parent invention hereto permited conventional surfing maneuvers, however, its structure did not optimally facilitate the generation of forward speed with which to perform such maneuvers. The "Acceleration Process" as now enabled by the Connected Structure improvement allows such forward speed to be attained. The Acceleration Process permits the rider to gain additional velocity in a manner analogous to how a child on a swing generates additional velocity and elevation. Given that the heart and soul of surfing is to enable a rider to enjoy the feel and power of increased velocity that results from cyclical transition between the supra-equidyne area and sub-equidyne area relative to a position of equilibrium, the Connected Structure is a significant improvement to the parent invention and prior art.

A third object of the subject invention is to to solve the transient surge problems associated with ride start-up and rider induced flow decay upon upwardly inclined flow surfaces. This solution results by lowering the downstream boundary area of the inclined flow forming surface at an angle so as to create a maximum height ridge line of decreasing elevation to facilitate self-clearing of undesirable transitory surges. This improvement is hereinafter referred to as the "Self-Clearing Incline".

A fourth object of the subject invention and a novel ramification to the "Self-Clearing Incline" occurs by extending the inclined flow forming surface and associated ridge line of the downstream boundary area to an increased elevation. If such increase in elevation is in excess of the net total head flow necessary to scale this new increase in elevation, then the flow will form a hydraulic jump and the sub-critical water thereof will spill down the upwardly sheeting flow in the manner of a spilling wave. This improvement is hereinafter called the "Inclined Riding Surface with Spilling Wave"). The spilling wave phenomena can also be incorporated into the other embodiments as described herein. A corollary improvement to any spilling wave application is a a properly configured vent system to handle the water which spills back down the flow forming surface. If such water remained unvented, it would eventually choke the entire flow. Consequently, to maintain a steady state

One object of the present invention is to improve upon the parent invention by providing a flow forming surface upon which a shallow water flow can produce a body of water that is similar to the kind prized by expert surfers, i.e., tunnel waves, which has a mouth and an enclosed tunnel extending for some distance into the interior of the forward face of the wave-shape. Such improvement is hereinafter referred to as the "Shallow Flow Tunnel Wave Generator." Heretofor, tunnel waves have only been available to surfers in a natural or deep water flow environment. The subject invention, through proper configuration of a flow forming surface and adequate shallow water flow characteristics (e.g., velocity, turbidity, depth, direction, etc.), can produce wave forms that have similar appearance and ride characteristics as "real" tunnel waves subject to certain ride conditions, e.g., limitation on surfboard fin size. However, the significant cost savings attributable to shallow flow construction and reduced energy consumption outweigh any limitations that may be imposed. The parent invention also provided for a stationary non-breaking upwardly inclined deep water flow shape for beginners. The subject invention will also improve upon this embodiment of the parent invention through the use of shallow water flow technology. Such improvement is hereinafter referred to as the "Shallow Flow Inclined Surface." In addition to the significant advantage of reduced cost, additional advantages to the shallow water improvements described above include, increased safety due to reduced deep water pool depth, reductions in water maintenance due to decrease in volume of water treated, and the opportunities to create novel water sports, e.g., flowboarding or inner-tube "bumper cars".

A second object of the subject invention is to provide a flow forming means (hereinafter referred to as the "Connected Structure") comprised of a substantially horizontal flat surface (the sub-equidyne area) that transitions by way of a radial concave arc (the equilibrium zone) connected to the supra-equidyne area (e.g., the inclined plane or tunnel wave generator). The Connected Structure facilitates a riders ability to maximize his forward speed by the riders own efforts of "pump-turning", hereinafter more fully described as the "Acceleration Process". Without benefit of said Connected Structure such increased speed would not be available. The Connected Structure encompasses the complete spectrum of surface flows and wave shapes desired by wave-riding and water skimming enthusiasts. Beginning at one extreme with a flat incline, and progressing by introduction of an increasing array of surface curvatures from the horizontal to the vertical combined with varying attitude and inclination of said surface relative to an upward (or downward, as the case may be) flow of water that culminates at the other extreme in a tunnel wave shape. A significant feature of the Connected Structure is how its unique configuration can dramatically improve the performance parameters of the parent invention's Inclined Surface

condition, to the extent that new water flows into the system, then, an equal amount of old water must vent out.

A fifth object of the subject invention is to improve by way of combination the tunnel and inclined flow forming surfaces, as well as, creation of an intermediate "spilling wave" that works in combination with the inclined flow surface. This embodiment is hereinafter referred to as the "Omni-Wave". A feature of the Omni-Wave embodiment is its unique flow forming shape can permit (by way of a progressive increase of the net head of the sheet flow) the transformation of a sheet water flow from a stationary "spilling wave" along the entire forming means, to a transitional "spilling wave" with inclined surface flow, to the final inclined surface flow and tunnel wave shape. This method is hereinafter referred to as the "Wave Transformation Process". The Omni-Wave and the Wave Transformation Process will offer an improved environment for the performance of surfing and water skimming maneuvers.

A sixth object of the present invention is to provide an apparatus that will enable riders to perform surfing and water skimming maneuvers in a format heretofore unavailable except by analogy to participants in the separate and distinct sports of skateboarding and snowboarding, to wit, half-pipe riding. In this regard, the present invention comprises a method and apparatus for forming a body of water with a stable shape and an inclined surface thereon substantially in the configuration of a longitudinally oriented half-pipe. Such improvement is hereinafter referred to as the "Fluid Half-Pipe." A corollary improvement to the Fluid Half-Pipe is to provide an apparatus that permits an increased throughput capacity by increasing the depth of the Fluid Half-Pipe in the direction of its length. This increase in depth will have the added benefit of causing a rider to move in the direction of fall and facilitate his course through the ride.

The final object of the present invention is the positioning of dividers within a Fluid Half-Pipe or Inclined Surface as described above and to prevent a "jet wash" phenomenon that can result in loss of a rider's flow. This "jet wash" phenomenon occurs when a rider who is positioned in the equilibrium or supra-equidyne area of a thin sheet flow gets his flow of water cut off by a second rider positioned with priority to the line of flow. The cutting off of water occurs in thin sheet flow situations due to the squeegee effect caused by the second rider's skimming vehicle. The improvement aids in preventing adjacent riders from cutting off their respective flows of water. Such Improvement is hereinafter referred to as "Sheet Flow Dividers."

Other objectives and goals will be apparent from the following description taken in conjunction with the drawings included herewith.

## BRIEF DESCRIPTION OF THE DRAWINGS

*See pages 22a, 22b and 22c*

## REFERENCE NUMERALS IN DRAWINGS

| | |
|---|---|
| 30 | Tunnel "Wave" Surface |
| 31 | Stem Portion of Tunnel Generator |
| 32 | Front Face of Tunnel Generator |
| 33 | Stern Arch |
| 34 | Upstream Edge |
| 35 | Downstream Edge |
| 36 | Back Surface |
| 37 | Sub-surface Structural Support |
| 38 | Flow Direction |
| 39 | Super-Critical Water Flow |
| 40 | Transition Point |
| 41 | Rider |
| 42 | Tunnel |
| 43 | ---------- |

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 11 is a profile view of a Tunnel "Wave" Generator configured for shallow waterflows.

FIGURE 12 is a contour map of Tunnel "Wave" Generator as set forth in FIGURE 11.

FIGURE 13 is a plan view of the range of horizontal attitude with respect to the direction of water flow that the wave generator can take and still form a tunnel wave.

FIGURE 14 is a view in profile of a typical cross-section disclosing the range of inclination of the forward face of the wave generator with respect to the direction of water and orientation to the vertical.

FIGURE 15 depicts a rider on the Tunnel Wave Generator.

FIGURE 16 is a profile view of the inclined surface.

FIGURE 17 is a cross-sectional view of the inclined surface as shown in FIGURE 16.

FIGURE 18 depicts a rider on the Inclined Surface.

FIGURE 19a is a profile view of the Connected Structure.

FIGURE 19b is a cross-section of FIGURE 19a.

FIGURE 20 depicts a surfer riding an Inclined Surface as improved by the Connected Structure and who is taking advantage of the elevation process.

FIGURE 21a is a profile view of the Self Clearing Incline.

FIGURE 21b is a cross-section of FIGURE 21a.

FIGURE 22 is a contour map of the Self-Clearing Tunnel Wave.

FIGURE 23a, FIGURE 23b, and FIGURE 23c are three views in profile that illustrate in time lapse sequence a self-clearing Inclined Surface.

FIGURE 24a and FIGURE 24b illustrate in time lapse sequence the self-clearing Tunnel Wave.

FIGURE 25 is a profile view of the Omni-Wave.

FIGURE 26a depicts the Omni-Wave with a spilling wave formed along its entire front face.

FIGURE 26b depicts the Omni-Wave with a clear inclined surface and a spilling wave.

FIGURE 26c depicts the Omni-Wave with a clear inclined surface and a Tunnel Wave.

FIGURE 26d depicts a Body Boarder performing water skimming maneuvers and a surfer performing surfing maneuvers on the Omni-Wave.

FIGURE 26e depicts a knee boarder riding the spilling wave.

FIGURE 26f depicts a water skier on the inclined surface and an inner-tube rider on the spilling wave.

FIGURE 27 shows in profile view of a novel embodiment for water sports - the Half Pipe.

FIGURE 28a shows an elevation of a typical Half Pipe.

FIGURE 28b shows an elevation of a Half Pipe with modified flow forming bottom to assist in capacity and rider through put.

FIGURE 29 illustrates in profile view an improvement to the Half Pipe to assist in increased through put capacity.

FIGURE 30 shows dividers in a shallow flow to avoid flow "jet wash."

44 Shallow Flow Inclined Surface

45 Sub-Surface Structural Support

46 Back Surface

47 Front Surface

48 Down Stream Ridge Line

49 Upstream Edge

50 Side Edge

51 Concave Curvature

52 Straight Incline

53 Concave/Straight Incline Transition Point

54 ----------

55 Straight/Convex Transition Point

56 Convex Curvature

57 Connected Structure

58 Supra-Equidyne Area

59 Transition Line (dashed)

60 Equilbrium Zone

61 Transition Line (dotted)

62 Sub-Equidyne Area

63 Surfer

64 Self Clearing Incline

65 Top Vent

66 Self-Clearing Tunnel Wave

67 Swale

68 Transient Surge

69 Omni-Wave

70 Stationary Spilling Wave

71 Kneeboard Rider

72 Innertube Rider

73 Water Skier

74 Fluid Half Pipe

75 ----------

76 ----------

77 Rider(s) - Dividers

78 Front Face - Dividers

79 Dividers

80 Body of Water

81 Water

82 Leading Edge

83 Down Flow Side

84 Flat Section

85 Up-Flow-Side

86 Trailing Edge

87 Receiving Pool

88 Rider(s) - Inner Tube

89 Half-Pipe Flow Forming Means

90 -------------

91 Dam

## DETAILED DESCRIPTION OF THE SUBJECT INVENTION

Because the original application, the continuation of the original application and the subject invention are operated in water, and many of the results of its passage there-through, or the propelling of water against the wave or flow forming means thereof, are similar to those caused by a boat hull, some of the terms used in the descriptions hereto will be nautical or marine terms; likewise, from the perspective of physical water dynamics, some of the terms used herein will be hydraulic engineering terms; and finally, from the

perspective of ride operation and function, some of the terms used herein will be terms as used in the sport of surfing; all such terms constitute a ready-made and appropriate vocabulary which is generally understood by those skilled in the art. To the extent that there are special terms, then, those terms are further defined herein.

Further, it will be understood by those skilled in the art that much of the description of structure and function of the wave generator and inclined surface of the original application and its continuation application may apply to the embodiments of the subject invention, to the extent used by this application. Therefore, the descriptions of the flow forming means/wave generator hull and inclined surface of the prior applications should also be read in conjunction with Figures 11-30. . However, to the extent there are any differences or descrepancies between the description and teaching of the prior applications and the subject invention, the description and teaching of the subject invention shall prevail.

Except where specifically limited, it is to be understood that the embodiments as described herein are to function in both deep and shallow flow environments. Furthermore, that the flow is to be supercritical (i.e., according to the formula $v > \sqrt{gd}$ where v = velocity, g = acceleration due to gravity ft/sec$^2$, d = depth of the sheeting body of water).

## DESCRIPTION OF SHALLOW FLOW TUNNEL "WAVE" GENERATOR

Turning now to FIG. 11 (isometric view) and FIG. 12 (contour map) there is illustrated a Tunnel "Wave" Generator 30 similar to the generator of prior application, however, improved to serve in a shallow water flow. Plan-sectional lines as revealed in FIG. 11 and contour lines as revealed in FIG. 12 are solely for the purpose of indicating the three-dimensional shape in general, rather than being illustrative of specific frame, plan, and profile sections. Tunnel Generator 30 is comprised of a stem 31, a front face 32, a stern arch 33, an upstream edge 34 running from stem 31 to stern arch 33 and acting as the upstream perimeter of front surface 32, a downstream edge 35 running from stem 31 to stern arch 33 and acting as the downstream perimeter of front face 32, back surface 36, and sub-surface structural support 37. Front surface 32, bounded by upstream edge 34, downstream edge 35 and stern arch 33 is that feature of Tunnel Generator 30 which effectively shapes its tunnel "wave". Moving in a direction as indicated by arrow 38, super-critical shallow water flow 39 originating from a water source (not shown) moves in a conforming flow upward over the front face 32 to form an inclined body of water in the shape of a tunnel "wave" (not shown) upon which a rider (not

shown) can ride. Back surface 36 is sufficiently smooth and with transitions analogous to a conventional waterslide such that a rider (not shown) could safely be swept over or around Tunnel Generator 30 to a termination pool or area (not shown) to properly exit. The outside dimensions of the flow forming front face 32 of Tunnel Generator 30 are capable of a broad range of values which depend more upon external constraints, e.g., financial resource, availability of water flow, etc, rather than specific restrictions on the structure itself. However, for purposes of scale and not limitation, in order to form a tunnel "wave" of adequate size to fully accommodate an adult user the outside dimensions of Tunnel Generator 30 should be approximately 1 to 3 meters in height and 3 to 12 meters in length.

At least three characteristics of front face 32 of Tunnel Generator 30 influence the size, shape, and angle, of the tunnel "wave", and each of them interacts with the others:

A. its shape (FIG. 11 and 12)
B. its attitude - its horizontal position or angle with respect to the direction of water flow (FIG. 13)
C. its inclination - its vertical position or angle with respect to the direction of water flow (FIG. 14);

Each characteristic of front face 32 is now discussed in detail:

A. SHAPE
Front face 32 of Tunnel Generator 30 has a complex shape, comprised of concave curvature, both vertically and horizontally, as indicated generally by the FIG 11 plan sections lines and FIG 12 contour lines. Such lines are substantially but not specifically illustrative of the range of possible shapes, as will now be explained more fully:

1 Vertically:
- a. the shape of the vertical curvature can be:
  - (1) substantially a simple arc of a circle or,
  - (2) preferably, an arc of a more complex changing curve, e.g.:
    - (a) ellipse;
    - (b) parabola;
    - (c) hyperbola; or
    - (d) spiral.

If a changing curve, it preferably changes from an opening curve (i.e., the ascending water encounters an increasing radius as it ascends front face 32) at stem 31 through a transition point 40; to a closing curve ( i.e., the ascending water encounters a decreasing radius as it ascends front face 32)

from transition point 40 to stern arch 33. A critical feature of Tunnel Generator 30 is that commencing at transistion point point 40, front face 32 begins to curve past the vertical. Curvature past the vertical from transition point 40 towards the stern arch 33 gradually increases from 0 to a maximum of 30 degrees. 10 degrees is preferred.

2. Horizontally:

a. the shape of the horizontal curvature can be:

(1) substantially an arc of a circle; or

(2) preferably, a portion of a more complex, changing, curve e.g.;

(a) ellipse;

(b) parabola;

(c) hyperbola; or

(d) spiral.

If a changing curve, it would open (i.e., have an increasing radius from stem to stern) for more rapidly moving water flows, and close (have a decreasing radius from stem to stern) for slower water flows.

B. ATTITUDE

As disclosed in FIG.13 the horizontal attitude of front face 32 with respect to direction 38 of water flow can vary only within certain limits otherwise the "tunnel" will not develop. Since front face 32 has concave curvature of varying degrees along its horizontal axis, for purposes of orientation an extension of upstream edge 34 is used to indicate varying horizontal attitudes of front face 32 therefrom. Accordingly, upstream edge 34 can vary from substantially perpendicular to the direction 38 of water flow to an angle of approximately 35 degrees, as shown.

C. INCLINATION

As disclosed in FIG. 14 , the inclination of the front face 32 with respect to the direction 38 of water flow is also limited, otherwise the tunnel will not be developed. Two factors are important with respect to inclination, first, the change in angle of incline relative to the depth of the water must be sufficiently gradual to avoid separation of flow lines/deflection. Second, the angle of release (as defined by a line tangent to front face 32 at downstream edge 35 when compared to the vertical) must be past the vertical as shown. Amounts past vertical may vary, however, a preferred amount is 10 degrees.

At least two other factors effect the size and shape of tunnel wave formation, i.e., flow velocity and water flow depth. The velocity of the water over Tunnel Generator 30 has a wide range, dependent upon the overall size of the Tunnel Wave Surface and the depth of water. In general, the flow is to be

supercritical (i.e., according to the formula $v > \sqrt{gd}$ where $v$ = velocity, $g$ = acceleration due to gravity $ft/sec^2$, $d$ = depth of the sheeting body of water). However, velocities in excess of that which is at a minimum necessary to achieve supercritical velocity are sometimes desired, e.g., to provide sufficient momentum transfer to support the weight weight component of a given rider, and to achieve the vertical heights required to form a tunnel "wave".

The depth of the water is primarily a function of the minimum necessary to permit a tunnel "wave" to form at a given height, and simultaneously enable the flow of water to support (via momentum transfer) the weight component of a contemplated range of users. Because of the operational requirements of momentum transfer, the depth of the water has direct relationship to the velocity of the water, i.e., the higher the velocity of flow, the lower the requisite depth. Since this embodiment is limited to shallow flows, the depth of water will range from approximately 2 to 40 centimeters.

Tunnel Generator 30 can be fabricated of any of several of well known materials which are appropriate for the use intended. Concrete; formed metal, wood, or fiberglass; reinforced tension fabric; air, foam or water filled plastic or fabric bladders; or any such materials which will stand the structural loads involved. A preferred embodiment includes a thick foamed plastic covering to provide additional protection for the riders using the facility.

Theoretically, no pool or water containment means is required for Tunnel Generator 30, in that the flow from a suitable flow source (e.g., pump and nozzle, fast moving stream or elevated reservoir/lake) is all that is required. However, where water recycling is preferred, then, low channel walls can be constructed to retain the flowing water with a lower collection pool, recycling pump and appropriate conduit connected back to the upstream flow source. The area of channel containment need be only large enough to allow the performance of appropriate water skimming maneuvers, since the curling water of the tunnel wave would remain more or less stationary with respect to the containment structure. Thus, such a structure could be constructed even in a back yard.

From the description above, a number of advantages of Tunnel "Wave" Generator 30 becomes evident:

(a) The energy required to produce a tunnel "wave" shape under shallow flow conditions is is dramatically less than that required under "natural" conditions, e.g., as

indicated in Killen's 1980 article, the power required to produce operational natural waves is proportional to the height of the wave raised to the 3.5 power ($hw^{3.5}$). Consequently, a 2 meter wave would require 11.3 times the power of a 1 meter wave or approximately 3.7 mega watts or 4800 horsepower. An 8 cm in depth shallow flow wave as contemplated by the subject invention with similar width to Killen's structure would be able to produce a 2 meter high tunnel "wave" for under 400 horsepower.

(b) The capital costs and operating costs for shallow water tunnel "wave" generation is substantially less than deep water installations.

(c) The sight, sound, and sensation of tunnel "wave" riding is a thrilling participant and observer experience, that has heretofor only been available to relatively few people in the world. The subject invention will enable this experience to be become more readily available.

(d) From a safety perspective, shallow water is generally perceived as safer in view of drowning.

## OPERATION OF THE TUNNEL "WAVE" SURFACE

FIG. 15 illustrates Tunnel Generator 30 in operation with the concavity of front face 32 acting to shape a water walled tunnel from super-critical shallow water flow 39 within and upon which rider 41 can ride. Water flow 39 originating from a water source (not shown) moves in a direction 38 as indicated. At stem 31 water flow 39 moves over front face 32 and onto back surface 36. Back surface 36 is sufficiently smooth and with transitions analogous to a conventional waterslide such that rider 41 could safely be swept over or around Tunnel Generator 30 to a termination pool or area (not shown) to properly exit. Progressing from transition point 40 to stern arch 33 the horizontal and vertical concavity of front face 32 acts as a scoop to channel and lift water into the central portion of front face 32 towards stern arch 33. Combined with the attitude of Tunnel Generator 30 relative to the direction 38 of water flow 39, the resultant forces thereto propel water flow 39 along the path of least resistance which is upward and outward creating the desired tunnel 42. Tunnel 42 size is adjustable depending upon the velocity of water flow 39, i.e., the higher the flow the larger the tunnel effect. The forward force component required to maintain rider 41 (including any skimming device that he may be riding) in a stable riding position and overcome fluid drag is due to the downslope component of the gravity force

created by the constraint of the solid flow forming surface balanced primarily by momentum transfer from the high velocity upward shooting water flow 39. Rider's 41 motion upslope (in excess of the kinetic energy of rider 41) consists of the force of the upward shooting water flow 39 exceeding the downslope component of gravity. Non-equilibrium riding maneuvers such as cross-slope motion and oscillating between different elevations on the "wave" surface are made possible by the interaction between the respective forces as described above and the use of the rider's kinetic energy.

Accordingly, it should now be apparent that Tunnel "Wave" Generator 30 embodiment of this invention can use shallow water flow in a water ride attraction to simulate ocean tunnel waves. In addition, Tunnel "Wave" Generator 30 has the following advantages:

- it requires a fraction of the energy utilized in generating a "real" wave;

- it costs substantially less to build and maintain;

- it allows a rider to experience the sight, sound, and sensation of tunnel wave riding, an experience that hereto for has not been available in commercial settings.

- it uses shallow water which is inherently safer than deep water in the prevention of drownings.

## DESCRIPTION OF SHALLOW FLOW INCLINED SURFACE

Turning now to FIG 16 there is illustrated Shallow Flow Inclined Surface 44. Plan-sectional lines as revealed in FIG. 16 are solely for the purpose of indicating the three-dimensional shape in general, rather than being illustrative of specific frame, plan, and profile sections. Shallow Flow Inclined Surface 44 is comprised of sub-surface structural support 45; back surface 46; and front face 47 which is bounded by an imaginary downstream ridge line 48, an upstream edge 49, and side edge 50a and 50b. Side edge 50 can have walls (not shown) or be connected with conventional broad surfaced downhill sliding transitions (not shown) to either contain or allow a rider to move out and off of the flow. Front face 47 can either be a gradual sloping inclined plane, a continuous concave planar surface, a concave planar surfacejoined to a convex planar surface, or preferably a combination of planar

curved surfaces and planar inclined surfaces. FIG 17 shows in cross-section a preferred profile of front face 47 with upstream edge 49 (indicated as a point in this cross-sectional view) as the upstream boundary and with a combination of curves and straight inclines as follows: concave curvature 51 as one moves upwards towards the downstream ridge 48 (indicated as a point in this cross-sectional view); concave curvature 51 transitioning to a straight incline 52 at a concave/straight transition point 53; straight incline 52 continuing to straight/convex transition point 55; and convex curvature 56 from straight/convex transition point 55 to downstream ridge 48. Back surface 46 joins front face 47 at the downstream ridge line 48. Back surface 46 is sufficiently smooth and with transitions analogous to a conventional waterslide such that a rider (not shown) could safely be swept over downstream ridge line 48 to a termination pool or area (not shown) to properly exit. Super-critical water flow 39 originating from a water source (not shown) moves in direction 38 to produce a conforming upward flow over front face 47, the downstream ridge line 48 and onto the back surface 46 to form an inclined body of water upon which a rider (not shown) can ride. The outside dimensions of the flow forming front face 47 of Shallow Flow Inclined Surface 44 are capable of a broad range of values which depend more upon external constraints, e.g., financial resource, availability of water flow, etc, rather than specific restrictions on the structure itself.

The velocity of the water over Shallow Flow Inclined Surface 44 has a wide range, dependent upon the overall size of the Inclined Surface and the depth of water. In general, the flow is to be supercritical (i.e., according to the formula $v > \sqrt{gd}$ where v = velocity, g = acceleration due to gravity ft/sec$^2$, d = depth of the sheeting body of water). However, velocities in excess of that which is at a minimum necessary to achieve supercritical velocity are sometimes desired, e.g., to provide sufficient momentum transfer to support the weight weight component of a given rider, and to achieve the vertical heights required to form an unbroken "wave".

The depth of the water is primarily a function of that which is necessary to successfully operate for the purposes intended. Because of the operational requirements of momentum transfer, the depth of the water has direct relationship to the velocity of the water, i.e., the higher the velocity of flow, the lower the requisite depth. Since this embodiment is limited to shallow flows, the depth of water will range from approximately 2 to 40 centimeters.

Shallow Flow Inclined Surface 44 can be fabricated of any of several of well known materials which are appropriate for the use intended. Concrete; formed metal, wood, or fiberglass; reinforced tension fabric; air, foam or water filled plastic or fabric bladders; or any such materials which will stand the

structural loads involved. A preferred embodiment includes a thick foamed plastic covering to provide additional protection for the riders using the facility.

Theoretically, no pool or water containment means is required for Shallow Flow Inclined Surface 44, in that the flow from a suitable flow source (e.g., pump and nozzle, fast moving stream or elevated reservoir/lake) is all that is required. However, where water recycling is preferred, then, low channel walls can be constructed to retain the flowing water with a lower collection pool, recycling pump and appropriate conduit connected back to the upstream flow source. The area of channel containment need be only large enough to allow the performance of appropriate water skimming maneuvers. Thus, such a structure could be constructed even in a back yard.

From the description above, a number of advantages of Shallow Flow Inclined Surface 44 becomes evident:

(a) The energy required to produce an unbroken "wave" shape similar to that simulated by Shallow Flow Inclined Surface 44 is dramatically less than that required under "natural" conditions, e.g., as indicated in Killen's 1980 article, the power required to produce operational natural waves is proportional to the height of the wave raised to the 3.5 power ($hw^{3.5}$). Consequently, a 2 meter wave would require 11.3 times the power of a 1 meter wave or approximately 3.7 mega watts or 4800 horsepower. An 8 cm in depth shallow flow wave as contemplated by the subject invention with similar width to Killen's structure would be able to produce a 2 meter high inclined surface "wave" for under 400 horsepower.

(b) The capital costs and operating costs for shallow water inclined surface "wave" generation is substantially less than deep water installations.

(c) The sight, sound, and sensation of inclined surface "wave" riding is a thrilling participant and observer experience, that has heretofor only been available to relatively few people in the world. The subject invention will enable this experience to be become more readily available.

(d) From a safety perspective, shallow water is generally perceived as safer in view of drowning.

## OPERATION OF SHALLOW FLOW INCLINED SURFACE

FIG. 18 illustrates Shallow Flow Inclined Surface 44 in operation. Super-critical water flow 39 originating from a water source (not shown) moves in direction 38 to produce a conforming upward flow over front face 47, the downstream ridge line 48 and onto the back surface 46 to form an inclined body of water upon which rider 41 can ride. Front face 47 serves as the primary riding area for rider 41. On this area rider 41 will be able to perform skimming maneuvers as follows: The forward force component required to maintain rider 41 (including any skimming device that he may be riding) in a stable riding position and overcome fluid drag is due to the downslope component of the gravity force (created by the constraint of sub-surface structural support 45) balanced primarily by momentum transfer from the high velocity upward shooting water flow 39. The motion of rider 41 in an upslope direction (in excess of the kinetic energy of rider 41) consists of the force of the upward shooting water flow 39 exceeding the downslope component of gravity. Non-equilibrium riding maneuvers such as cross-slope motion and oscillating between different elevations on the "wave" surface are made possible by the interaction between the respective forces as described above and the use of rider's 41 kinetic energy. Back surface 36 is sufficiently smooth and with transitions analogous to a conventional waterslide such that rider 41could safely be swept over downstream ridge line 48 to a termination pool or area (not shown) to properly exit.

Accordingly, it should now be apparent that Shallow Flow Inclined Surface 44 embodiment of this invention can use shallow water flow in a water ride attraction to simulate unbroken ocean waves. In addition, Shallow Flow Inclined Surface 44 has the following advantages:

- it requires a fraction of the energy utilized in generating a "real" wave;
- it costs substantially less to build and maintain;
- it allows a rider to experience the sight, sound, and sensation of continuous unbroken wave riding, an experience that hereto for has not been available in commercial settings. Such capability will greatly expand the training of beginning "surf-riders" and provide a venue for surf-camps, etc.

• it uses shallow water which is inherently safer than deep water in the prevention of drownings.

## DESCRIPTION OF CONNECTED STRUCTURE

The Connected Structure creates additional surface area beyond the areas defined by Tunnel Wave Generator 30 and Shallow Flow Inclined Surface 44. In general terms, this expanded area can be described as a horizontal area upstream of the upstream edge of each respective embodiment. Furthermore, the Connected Structure describes specific ratios between three distinct regions that can be defined to exist on Tunnel Wave Generator 30 and Shallow Flow Inclined Surface 44 as improved by the Connected Structure. Through combination of area expansion and defined region size relationships, a flow forming means can be described with performance characteristics as yet undisclosed by the prior art.

Turning now to FIG. 19a, we see a generalized diagram of an improvement for a flow forming means herein called Connected Structure 57. Plan-sectional lines as revealed in FIG. 19a are solely for the purpose of indicating the three-dimensional shape in general, rather than being illustrative of specific frame, plan, and profile sections. Connected Structure 57 is comprised of a supra-equidyne area 58 which transitions (as represented by a dashed line 59) to an equilibrium zone 60, which in turn transitions (as represented by a dotted line 61) to a sub-equidyne area 62. The dimensions and relationship of Connected Structure's 57 sub-equidyne 62, equilibrium 60, and supra-equidyne 58 areas are described as follows:

FIG. 19b illustrates a cross-section of Connected Structure 57, with sub-equidyne area 62, equilibrium zone 60, and supra-equidyne area 58 with a range of configurations 58a, 58b, and 58c that are capable of producing a flow that ranges from the previously described unbroken "wave" (i.e., inclined flow) and the tunnel "wave" flow.

The preferred embodiment for the breadth of the sub-equidyne area 56 in the direction of flow 38 is, at a minimum, one and one half to four times the verticle height (as measured from sub-equidyne to the top of supra-equidyne) of the total flow forming means. The larger breadth would apply to low elevation means (e.g. 1 meter) and smaller breadth to high elevation means (e.g., 6 meters). Sub-equidyne 62 orientation is substantially horizontal and normal to the force of gravity.

The preferred embodiment for the shape of equilibrium zone 60 can be defined by a portion of a changing curve., e.g., an ellipse; parabola; hyperbola; or spiral. If a changing curve, the configuration of equilibrium zone 60 is substantially arcs of a closing curve (i.e., the ascending water encounters a decreasing radius as it ascends the face of the flow forming means). The radius of said closing curve being at its smallest approximating the radius of supra-equidyne 58 leading edge, and at its longest less than horizontal. For purposes of simplicity and scale (but not by way of limitation) the uphill breadth of equilibrium zone 60 can generally be defined by a distance approximately equal to the length of the rider's flow skimming vehicle, i.e., approximately three to ten feet.

The preferred embodiment for the shape of supra-equidyne area 58 can be defined by a portion of a changing curve., e.g., an ellipse; parabola; hyperbola; or spiral. If a changing curve, the configuration of supra-equidyne area 58 is initially arcs of a closing curve (i.e., the ascending water encounters a decreasing radius as it ascends the face of the flow forming means). The radius of said closing curve is at its longest always less than the radius of the longest arc of equilibrium zone 60, and, at its smallest of sufficient size that a rider could still fit inside a resulting "tunnel wave". On the opposite end of the spectrum, said arcs of a closing curve can transition, after a distance at least equal to 2/3's the length of the riders flow skimming vehicle (approximately two to seven feet), to arcs of an opening curve (i.e., the ascending water encounters an increasing radius as it ascends the face of the flow forming means). The only limitation as to the overall breadth of supra-equidyne area 58 in the direction of flow 38 is the practical limitation of available head of an upwardly sheeting flow.

Super-critical water flow 39 originating from a water source (not shown) moves in direction 38 to produce a conforming flow over sub-equidyne area 62, equilibrium zone 60, and supra-equidyne area 58 to form an inclined body of water upon which a rider (not shown) can ride and perform surfing or water skimming maneuvers that would not be available but for such Connected Structure 57.

## OPERATION OF THE CONNECTED STRUCTURE

The significance Connected Structure 57 is a function of how it can be used to enable the performance of surfing and water skimming maneuvers. Essential to the performance of modern surfing and skimming maneuvers are the

elements of oscillation, speed, and proper area proportion in the "wave" surface that one rides upon. Each element is elaborated as follows:

OSCILLATION: The heart and soul of modern surfing is the opportunity for the rider to enjoy substantial oscillation between the supra-critical and sub-critical areas. As one gains expertise, the area of equilibrium is only perceived as a transition area that one necessarily passes through in route to supra and sub critical areas. Oscillatory motion has the added advantage of allowing a rider to increase his speed.

SPEED: Speed is an essential ingredient to accomplish modern surf maneuvers. Without sufficient speed, one cannot "launch" into a maneuver. The method and means for increasing one's speed on a properly shaped wave face can be made clear by analogy to the increase of speed on a playground swing as examined in SCIENTIFIC AMERICAN, March 1989, p. 106-109. On a swing, if one is crouching at the highest point of a swing to the rear, ones energy can be characterized as entirely potential energy. As one descends, the energy is gradually transformed into kinetic energy and one gains speed. When one reaches the lowest point, one's energy is entirely kinetic energy and one is moving at peak speed. As one begins to ascend on the arc, the transformation is reversed: one slows down and then stops momentarily at the top of the arc. Whether one goes higher (and faster) during the course of a swing depends on what one has done during such swing. If one continues to crouch, the upward motion is a mirror image of the downward motion, and ones center of mass ends up just as high as when one began the forward swing. If instead one stands when one is at the lowest point, i.e., "pumping" the swing, then one would swing higher and faster.

The importance of sub-equidyne area 62 in the context of the previous discussion of swing dynamics, is that sub-equidyne area 62 is by its nature the lowest point on Connected Strucuture 57 and on a wave. Standing/extending at this low point results in a larger increase of speed than if one stood at any other point on Connected Structure 57 or on a wave. This increase in speed and total kinetic energy is due to two different mechanistic principals, both of which may be utilized by a rider on Connected Structure 57 or a wave. By standing at the lowest point in the oscillatory path, the center of gravity of the rider is raised allowing a greater vertical excursion up the slope than the original descent. Crouching at the top of the path and alternately standing at the bottom allows an increase in vertical excursion and restoration of energy lost to fluid drag. Additionally, the other mechanism, increasing the kinetic energy, is due to the increase in angular rotation. As the rider in his path rotates around a point located up the wave face, extension/standing at the low point increases his angular velocity, much in the

same manner as a skater by drawing in his/her arms increases his/her rotational speed due to the conservation of momentum. However, kinetic energy increases due to the work of standing against the centrifugal force and because kinetic energy is proportional to the square of angular velocity, this increase in kinetic energy is equivalent to an increase in speed.

PROPER AREA PROPORTION: Connected Structure 57 as a flow forming surface combines in proper proportion the sub-critical 62, equilibrium 60, and supra-critical 58 areas so as to enable a rider to oscillate, attain the requisite speed and have available the requisite transition area for performance of modern day surfing and skimming maneuvers that would not be possible, but for said Connected Structure 57.

Turning to Figure 20 there is illustrated a surfer 63 on an inclined surface as improved by Connected Structure 57 in various stages of a surfing maneuver. Surfer 63 is in a crouched position on supra-equidyne area 58 and gathering speed as he moves downward over a conformed sheet of super-critical water flow 39 which originates from a water source (not shown) and moves in direction 38. Upon reaching the low point at sub-equidyne area 62, surfer 63 extends his body and simultaneously carves a turn to return to supra-equidyne area 58. As a consequence of such maneuvering, surfer 63 will witness an increase in speed to assist in the performance of additional surfing maneuvers. The process by which a surfing or water skimming rider can actively maneuver to increase his speed is referred to as the Acceleration Process.

## DESCRIPTION OF SELF-CLEARING INCLINE AND TUNNEL WAVE

Turning to FIG. 21a (isometric view) and FIG. 21b (cross-sectional view) there is illustrated a top vent self-clearing incline improvement for Shallow Flow Inclined Surface (as improved by Connected Structure) all of which is hereafter referred to as a Self-Clearing Incline 64. Self-Clearing Incline 64 is comprised of Shallow Flow Inclined Surface as modified by lowering the elevation of side edge 50b' and causing downstream ridge line 48 to incline from the horizontal and form a top vent 65. FIG. 21b superimposes a cross-sectional profile of side edge 50a over the lowered side edge 50b'. To have a noticeable effect, the angle of inclination should be at a minimum 5 degrees.

Turning to FIG. 22 (contour map) there is illustrated a swale self-clearing incline improvement for Tunnel "Wave" Generator 30 (as improved by Connected Structure 57) all of which is hereafter referred to as Self-Clearing Tunnel Wave 66, comprised of sculpting from front surface 32, sub-equi-dyne

area 62 and structural matrix support 37 (not shown) a shallow venting swale 67. All surfaces of swale 67 are smooth and without edges.

## OPERATION OF SELF-CLEARING INCLINE AND TUNNEL WAVE

Self-Clearing Incline 64 and Self-Clearing Tunnel Wave 66 are designed to prevent unwanted turbulent white water build-up that fails to clear from the riding surface in the usual manner of "washing" over the downstream ridge of these respective embodiments. In practice, this vent problem will only occur if there is a restriction on flow venting to the side of the inclined surface or generator, e.g., a channel wall, or where there is a tremendous amount of activity, e.g., multiple riders on the surface of the water.
This undesirable build-up is particularly acute in an upward directed flow. This build-up will most likely occur during three stages of operation, (1) water flow start-up with no rider present; (2) transferring the kinetic energy of high speed water flows to a maneuvering rider; and (3) cumulative build-up of water due to a spilling wave. In the start-up situation (1) , due to the gradual build up of water flow associated with pump/motor phase in or valve opening, the initial rush is often of less volume, velocity or pressure than that which issues later. Consequently, this initial start water is pushed by the stronger flow, higher pressure, or faster water that issues thereafter. Such pushing results in a build-up of water (a hydraulic jump or transient surge) at the leading edge of the flow. An upward incline of the riding surface serves only to compound the problem, since the greater the transient surge, the greater the energy that is required to continue pushing such surge in an upward fashion. Consequently, the transient surge will continue to build and if unrelieved will result in overall flow velocity decay, i.e., the slowed water causes additional water to pile up and ultimately collapse back onto itself into a turbulent mass of bubbling white water that marks the termination of the predominantly unidirectional super-critical sheet flow. In the situation of kinetic energy transfer (2), when a maneuvering rider encounters faster flowing water or water that is moving in a direction different than the rider, a transient surge builds behind the rider. Likewise, if this transient surge grows to large it will choke the flow of higher speed unidirectional super-critical sheet flow, thus, causing flow decay. In the situation of an excessive build up of water over time from a spilling wave(3), the interference of a preceding flow with a subsequent flow can result in an undesired transient

surge and flow decay at a point near where the two flows meet. Under all three conditions, it is possible to control or eliminate the transient surge by immediately increasing the flow pressure and over-powering or washing the transient surge off the riding surface. However, there comes a point where the build-up of water volume is so great that for all practical purposes over-powering is either impossible, or at best a costly solution to a problem capable of less expensive solution. Such less expensive solution is possible by the introduction of vents.

Two classes of vent mechanisms are identifiable. The first class, top vents, are used to clear transient surges from inclined surfaces. FIG. 23a, 23b, and 23c show in time lapse sequence how the design of top vent 64 operates to solve the problem of a pressure/flow lag during start-up. In FIG. 23a water flow **39** has commenced issue in an uphill direction from water source (not shown) in direction 38. As water flow 39 moves up front surface 47, the leading edge of water flow is slowed down by a combination of the downward force of gravity and friction with front surface 47, whereupon, it is overtaken and pushed by the faster and stronger flow of water that subsequently issues from the water source. The result of this flow dynamic is that a transient surge **66** begins to build. However, as transient surge **66** builds, it reaches the height of low side edge 50b' and commences to spill over onto back surface 46. FIG 23b shows this start procedure moments later wherein the water pressure/flow rate from the water source has increased and transient surge **66** has moved further up the incline. FIG 23c shows the final stage of start-up wherein the transient surge has been pushed over the top of Down Stream Ridge Line 48 and water flow **39** now runs clear. Similar to the start-up procedure, when a lower speed rider encounters the higher speed water, or when an accumulative build-up of water results from a spilling wave, a transient surge may occur. In like manner, the transient surge will clear by spilling off to the lowered side accordingly.

The second class of vent mechanism, swale vents, are used to assist in clearing transient surges from tunnel wave generators. FIG. 24a and 24b show in time lapse sequence how the design of swale 65 operates to solve identical problems as suffered by the inclined surfaces with channel walls. In FIG. 24a water flow **39** has commenced issue in an uphill direction from water source (not shown) in direction 38. Transient surge **66** begins to build. However, as transient surge **66** builds, it commences to vent into swale 65, thus, permitting tunnel wave 42 to properly form as shown in FIG. 24b.

**DESCRIPTION AND OPERATION OF THE OMNI-WAVE**

FIG. 25 depicts a preferred embodiment herein named an Omniwave 69 comprised of Self-Clearing Incline 64 which is interconnected and continuous with Self-Clearing Tunnel Wave 66.

FIG. 26a, FIG. 26b, FIG. 26c, FIG. 26d, FIG. 26e and FIG. 26f illustrates Omni-Wave 69 on operation. A unique feature of Omni-Wave 69 is its unique flow forming shape can permit (by way of a progressive increase of the net head of the water flow) the transformation of super-critical water flow 39 that originates from a water source (not shown) in direction 38 to a stationary spilling wave 70 along the entire forming means (as illustrated in FIG 26a); to a stationary spilling wave 70 with Self Clearing Incline 64 flow (as illustrated in FIG 26b); to a Self-Clearing Incline 64 and Self-Clearing Tunnel Wave 66 flow (as illustrated in FIG 26c). This progressive wave forming method is hereinafter referred to as the "Wave Transformation Process". The Omni-Wave and the Wave Transformation Process will offer an improved environment for the performance of surfing and water skimming maneuvers. FIG. 26d shows surfer 63 and rider 41 on Self-Clearing Tunnel Wave 66 and Self-Clearing Incline 64 respectively. FIG. 26e shows surfer water skimming kneeboarder riding upon stationary spilling wave 70. FIG. 26f shows inner-tube rider 72 and water skier 73 on stationary spilling wave 70 and Self-Clearing Incline 64 respectively.

## DESCRIPTION AND OPERATION OF THE ~~FLUID~~ HALF PIPE

Turning to FIG. 27 wherein an apparatus is revealed that will enable riders to perform surfing and water skimming maneuvers in a format heretofore unavailable except by analogy to participants in the separate and distinct sports of skateboarding and snowboarding, to wit, half-pipe riding. Fluid Half Pipe 74, comprises a method and apparatus for generating a body of water 80 with a stable shape and an inclined surface thereon substantially in the configuration of a half-pipe with the opening of said half-pipe facing in an upwards direction. The water 81 which supplies said body of water flows over the leading edge 82 of the half-pipe flow forming means 89 and down one side (hereinafter referred to as the down-flow-side 83), in a direction perpendicular to the length of said half-pipe, across an appropriate sub-equidyne flat section 84, and up and over the other side of the half-pipe (hereinafter referred to as the up-flow-side 85 ), across the trailing edge 86, and into an appropriate receiving pool 87 or other suitably positioned Fluid Half Pipe or attraction. A rider 88a enters the flow at any appropriate point, e.g., sub-equidyne flat section 84, wherein as a result of his initial forward momentum of entry, the excessive drag of his water-skimming vehicle, and the

added drag of the riders weight induced trim adjustments to his riding vehicle, said rider (now 88b) is upwardly carried to a supra critical area in the upper regions of up-flow-side 85 near the half pipe's trailing edge 86, wherein as a result of the force of gravity in excess of the drag force associated with the riding vehicle and the riders own weight induced trim adjustments to reduce drag, rider (now 88c) hydro-planes down the up-flow-side 85, across the sub-equidyne flat 84, and performs a turn on down flow side 83 to return to up-flow-side 85 and repeat the cycle.

As can be appreciated by those skilled in the art, Fluid Half-Pipe 74 will offer its participants a consistent environment in which to perform known surfing and water skimming maneuvers, and due to the combination of up-side-flow, flat, and down-side-flow a unique environment in which to perform new maneuvers unachievable on existing wave surfaces.

The preferred embodiment for the breadth of the flow forming means 89 of Fluid Half-Pipe 74 approximates Connected Structure 57 joined to its mirror image at the midpoint of sub-equidyne 84. It is preferred that said width remain constant for the length of flow-forming means 89, however, variations in width with resultant variations in cross-sectional shape are possible. The limitations on minimum and maximum width is a function of ones ability to perform surfing maneuvers. If the flow forming means is too narrow, a rider would be unable to negotiate the transition from the up-flow side 85 to the down-flow-side 83 or vice versa. If too wide, a rider would not be able to reach or utilize the down-flow side 83 to perform surfing maneuvers.

A preferred embodiment for the length of the flow forming means of Fluid Half-Pipe 74 is at a minimum a length sufficiently wide to perform surfing and water skimming maneuvers thereon, and at a maximum a function of desire and/or budget.

A preferred embodiment for the cross-sectional shape of the up-flow side's flow forming means has been shown in FIG. 19b and discussed above. Fig. 19b illustrated a detailed cross-section of Connected Structure 57, with sub-equidyne area 62, equilibrium zone 60, and supra-equidyne area 58. Caution must be taken in the design of the up-flow-side 85 supra-equidyne area to insure proper water flow up and over the trailing edge 86. Excessive steepness or height that results in untimely or improperly located spilling or tunneling waves can result in an excessive build up of turbulent white water in the sub-equidyne flat area 84 which may culminate in complete deterioration of the up-side-flow. However, since advanced riders, in order to maximize speed and perform certain maneuvers, e.g., aerials, prefer a steep supra critical area that approaches or exceeds verticle, then, it is preferred that

spilling or tunnel wave formation (if any) be limited to areas adjacent the side openings of half-pipe 74, and that the majority middle half pipe 74 be substantially the shape as illustrated in FIG. 19b with supra-equidyne configuration 58a.

Generally, the elevation of half-pipe 74 leading edge 82 will exceed its line-of-flow position on half-pipe 74 trailing edge 86. This differential in elevation will insure that the water of said body of water 81 will have sufficient dynamic head to overcome all internal and external friction that may be encountered in its circuit down, across, up, and over flow forming means 89. The preferred ratio by which the down-flow-side exceeds the up-flow-side ranges from a minimum of ten to nine to a maximum of ten to one. It is also preferred that the respective leading & trailing edge 82 and 86 remain at constant elevations along the length of the half-pipe. Variations in elevation are possible, however, source pool water 81 dynamics, receiving pool water 87 dynamics, and maintenance of line of flow dynamic head must be accounted for.

In cross-sectional profile, a standard configuration for Fluid Half Pipe 74 is illustrated in FIG. 28a. In this standard configuration the cross-sectional elevation, width, and depth remains constant for the length of half-pipe 74. FIG 28b. illustrates an asymmetrical configuration, wherein, the leading and trailing edges 82 and 86 remain at constant elevations and the width between trailing edges remains constant, however, the distance between trailing edges and the flat sub-equidyne section 84 continues to increase at a constant rate of fall. The object of this particular asymmetrical embodiment is to increase throughput capacity for half-pipe 74 as the result of rider movement in the direction of fall due to the added vector component of gravity force ascribed to the weight of the rider in the direction of fall.

The preferred velocity of water in the subject invention is substantially a function of the overall drop in distance from leading edge 82 to the flat area 84. Consequently, previously discussed preferences in the overall height of the Connected Structure dictate the preferred water velocity. Such velocity can be calculated in accordance with Bernoulli's equation $v = \sqrt{2gz}$ where v is the velocity in feet per second, g is gravity ft/sec$^2$ and z = vertical distance dropped in feet.

The preferred depth of water is that which is required to perform surfing maneuvers. For purposes of Half Pipe 74 the minimum depth is 2 cm. and the maximum depth is whatever one might be able to afford to pump. An additional preference is that the water avoid excessive turbulence that results from a

hydraulic jump which occurs when the velocity of a sheeting body of water exceeds a certain critical velocity at a certain minimum depth.

Variations in the breadth and longitudinal movement of the body of water that flows upon the half-pipe can result in enhancements to rider through-put capacity for the Fluid Half Pipe. FIG. 29 depicts a half-pipe configured flow forming means 89. A stably shaped body of water 80a is situated on one side 89a of said flow forming means. The water 81 which supplies said stably shaped body of water is limited by a dam 91a to just one-half of the flow forming means 89. Riders 88a,b,c,&d enter the flow at any appropriate point, e.g., the sub-equidyne flat section 84 and perform water skimming maneuvers thereon. As shown in FIG 29, the water skimming maneuvers are performed using an inner-tube type vehicle. After an elapsed period of time, e.g., several minutes, a dam 91b is positioned to block the water 81 which supplies the stably shaped body of water 80a on side 89a of said flow forming means. Upon blockage of the source of water, the stably shaped body of water 80a soon ceases to exist on side 89a of said flow forming means. Consequently, the riders 88a,b,c,&d drift to the sub-equidyne section 84 and can easily exit. Simultaneous with, or shortly after the blockage by dam 91b, dam 91a opens and water 81 begins to flow over flow forming means 89b, whereupon forming a stably shaped body of water 80b that remains situated on side 89b. Riders 88e,f,&g enter the flow and commence to perform water skimming maneuvers for their alloted time span, whereupon dam 91a is re-positioned and the cycle is set to repeat.

FIG. 30 illustrates super-critical water flow 39 originating from a water source (not shown) moving in direction 38 to produce a conforming upward flow over front face 78. Dividers 79 provide separation for the individual riders 77a, 77b, and 77c and to prevent a "jet wash" phenomenon that can result in loss of a rider's flow. This "jet wash" phenomenon occurs when a rider who is positioned in the equilibrium or supra-equidyne area of a thin sheet flow gets his flow of water cut off by a second rider positioned with priority to the line of flow. The cutting off of water occurs in thin sheet flow situations due to the squeegee effect caused by the second rider's skimming vehicle.

As will be recognized by those skilled in the art, certain modifications and changes can be made without departing form the spirit or intent of the present invention. For example, the curvatures given as examples for the Connected Structure do not have to be geometrically precise; approximations are sufficient. The same is true of limits in angles, radii and ratios. The temperature and density of the water will have some difference although the

range of temperatures in which surfer/riders would be comfortable is fairly limited.

The terms and expressions which have been employed in the foregoing specifications are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described, or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.